

# PATENT SPECIFICATION

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## (54) IMPROVEMENTS IN AND RELATING TO HEAT-EXCHANGE TUBING

(71) We, NORANDA METAL INDUSTRIES, INC., a corporation organised and existing under the laws of the State of Delaware, United States of America, of 1530 Curtis Road, Bellingham, County of Whatcom, State of Washington, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of forming heat-exchange tubing, particularly to finned heat-exchange tubing.

The type of heat-exchange tubing with which the present invention is concerned is provided with inwardly extending fins, or so-called "inner" fins, on its peripheral wall. Tubing of this type is well known for its heat-exchange properties which vary from good to excellent, depending on the inner-fin pattern and size, the particular heat-exchange application, and other factors. However, even this type of tubing does not lend itself to certain exacting heat-exchange requirements for various applications. There are several reasons for this, and chief among them is that heat-exchange of the fins and also the peripheral wall of such tubing with fluid passing through the latter is inadequate for certain purposes regardless of the height and number of the fins.

In accordance with the present invention there is provided a method of forming heat-exchange tubing, which comprises providing a round metal tube blank having a longitudinal axis, a peripheral wall about said axis, and longitudinal inner fins on said wall, said fins being of equal height and spaced from said axis; and partially flattening the blank from two opposite sides into a substantially oblong cross-section with two opposite, parallel wall sections spaced apart such that the fins on one opposite wall section extend with their tips at least to the level of the tips of the fins on

the other opposite wall section. In thus forming the heat-exchange tubing, which may aptly be termed "flat" tubing, the number, height, spacing and direction of the fins therein may be selected from the wide variety of fin patterns and sizes which may readily be formed in round tubular blanks according to different known methods, but which could hardly, and never practically, be formed in flat tubing. Moreover, extreme simplicity characterizes the reformation of a round inner-fin tube blank into flat tubing of this kind in accordance with the present method, as by passing the round blank between rotary companion rolls or drawing the same through a die, all in a single pass, for example. Moreover, reformation in this fashion of a round tube blank particularly with helical inner fins into flat tubing of this type brings the fins into an entirely new and extremely effective cooperative relation, in that the then straight fins on the respective flat wall sections abut and are inclined to and cross each other, with the result that these fins sharply divide and divert into different directions at each cross-section of the tubing much of the fluid flowing through the entirely finned passage in the tubing.

The present invention seeks to form heat-exchange tubing of this type according to the aforementioned method, and which is subsequently further deformed in cross-sectionally or longitudinally curved fashion, thereby to reinforce the tubing against spread-apart of their opposite flat wall sections under pressure from fluid passing through the tubing.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 is a plan view of heat-exchange tubing formed by a method according to the present invention;

Figs. 2 and 3 are sections through the tubing taken on the lines 2—2 and 3—3, respectively, in Figs. 1 and 2;

Fig. 4 is a cross-section through a round

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inner-fin tub blank from which the tubing of Figs. 1 to 3 is fashioned;

Fig. 5 is a section through the tube blank on the line 5—5 in Fig. 4;

5 Fig. 6 is a cross-section through a second embodiment of heat-exchange tubing formed by a method according to the present invention;

10 Fig. 7 is a section through the tubing substantially along the line 7—7 in Fig. 6;

Fig. 8 is an enlarged section through part of the tubing substantially along the line 8—8 of Fig. 7;

15 Fig. 9 is a cross-section through a third embodiment of heat-exchange tubing formed by a method according to the present invention;

Fig. 10 is a section through the tubing of Fig. 9 along the line 10—10 thereof;

20 Fig. 11 is a cross-section through a fourth embodiment of heat-exchange tubing formed by a method according to the present invention;

25 Fig. 12 demonstrates a step in the formation of heat-exchange tubing by a method in accordance with the present invention;

30 Fig. 13 demonstrates a modified step in the formation of heat-exchange tubing by a method in accordance with the present invention;

35 Fig. 14 is a cross-section through a fifth embodiment of heat-exchange tubing formed by a method according to the present invention;

Fig. 15 is a side view, partly in section, of a heat exchanger embodying the heat-exchange tubing;

40 Fig. 16 is a section through the heat-exchanger along the line 16—16 in Fig. 15;

Fig. 17 is a side view, partly in section, of a modified heat-exchanger embodying the heat-exchange tubing;

45 Fig. 18 is a view of the heat-exchange tubing with a longitudinal twist;

Fig. 19 is a section through the heat-exchange tubing which is also cross-sectionally curved;

50 Fig. 20 is a perspective view of the heat-exchange tubing which is also bent longitudinally into successive helical turns;

55 Fig. 21 is a cross-section through a sixth embodiment of heat-exchange tubing formed by a method in accordance with the present invention;

Fig. 22 is a cross-section through a round finned tube blank from which the heat-exchange tubing of Fig. 21 is fashioned; and

60 Fig. 23 is a cross-section through a seventh embodiment of heat-exchange tubing formed by a method in accordance with the present invention.

65 Referring to the drawings, and more particularly to Figs. 1 to 3 thereof, the reference numeral 10 designates heat-exchange tubing having a peripheral metal

wall 12 of oblong cross-section and a multitude of metal fins 14 with tips 16. The peripheral wall 12 provides two flat opposite, and preferably parallel, wall sections 18, and opposite side wall sections 20 which join the flat wall sections 18, with the flat wall sections 18 constituting in this instance a far predominant part of the wall 12. The fins 14, which project inwardly from the wall 12 and are preferably formed integrally therewith, are of the same height which is such that the fins on either flat wall section 18 extend with their tips 16 to the level of the tips of the fins on the opposite flat wall section (Fig. 2), so that the entire interior of the flat tubing is within reach of the fins. Successive fins 14 on the wall 12 are preferably equally spaced, and the fins on either flat wall section 18 extend parallel to each other and at an inclination to the longitudinal axis  $x$  of the tubing, with the fins on the respective wall sections 18 being also inclined to and crossing each other (Fig. 3).

With the interior of the flat tubing being within full reach of the fins 14, the entire passage through the tubing is divided into individual flow channels 22, which makes for good heat-exchange between the fluid passing through the tubing and the fins 14 as well as peripheral wall 12 of the tubing. Heat-exchange between such fluid and the fins and peripheral wall of the tubing is even enhanced by the inclination to each other of the channels 22 on the opposite flat wall sections 18 (Fig. 3), in that they sharply divide and divert into different channels much of the fluid passing therein at each cross-section of the tubing.

The "flat" metal tubing 10 is advantageously formed from a round inner-fin tube blank 24 (Figs. 4 and 5) in accordance with an exceedingly simple method. For reasons more fully apparent hereinafter, the peripheral wall of the blank 24 is of the same thickness and peripheral extent as the wall 12 of the flat tubing 10, and the fins of the blank are of the same height and thickness, and also spaced, as the fins 14 of the tubing, wherefore the peripheral wall and fins of the blank are appropriately designated by the reference numerals 12 and 14, respectively, i.e., the same as their counterparts of the flat tubing. Further, the fins 14 on the round wall 12 of the blank 24 extend longitudinally helically at the same helix angle throughout (Fig. 5).

The inner-fin tube blank 24 itself may be formed in any known manner, including brazing or otherwise joining inserted fins to the round wall of the blank, but preferably by displacement, according to different known methods, of metal from the wall of the blank into grooves on a mandrel therein to form the fins 14 integral with the wall.

One such method is disclosed in the prior United States patent No. 3,422,518, dated January 21, 1969, with this method involving externally swaging a cylindrical tube blank against a grooved mandrel therein in a single pass of the blank over and beyond the mandrel, whereby metal from the blank wall is displaced into the mandrel grooves to form the fins. This method is preferred, not only because the same is highly efficient and readily lends itself to the formation of an inner-fin tube blank of most any desired fin pattern and size, but also because the swaging of the blank over the mandrel entails quite extensive elongation of the blank. Such extensive elongation of the blank and the formation of the fins exclusively by metal from the blank wall entail a considerable reduction of the wall thickness of the finished inner-fin tube blank, which is highly advantageous in point of heat-exchange of the tube wall, and hence also the entire tube, with a surrounding temperature-modifying medium, such as a coolant, for example.

The method of forming the inner-fin tube blank 24 into the flat tubing 10 simply involves partially flattening the blank to form opposite peripheral wall portions thereof into the flat parallel wall sections 18, which concludes the formation of the flat tubing 10. Such partial flattening of the round blank 24 may be achieved in any suitable manner, as by passing the blank between rotary companion rolls 30 and 32 in the direction of the arrow 34 (Fig. 12), or by drawing the blank through a die 36 in the direction of the arrow 38 (Fig. 13).

It follows from the preceding that the peripheral wall 12 of the flat tubing 10 is indeed the same wall 12 of the blank 24 which remains of the same thickness and peripheral extent. It is now also apparent that the fins 14 of the blank 24 and of the flat tubing 10 are indeed the same and retain their height and thickness as well as their spacing from each other. Further, in the course of partially flattening the round blank 24, the helically extending fins 14 will, over the extent of the flat wall sections 18 of the tubing, be extended into straight disposition (Fig. 3).

To bring the fins 14 for all practical purposes within full reach of the interior of the flat tubing 10, the fins in the round tube blank must obviously be spaced some distance from the axis of the blank. In this connection, it has been found that for a given inside diameter of the blank, the fin height may vary widely from less than the thickness of the peripheral blank wall to many times such wall thicknesses, with the fins of any height within this wide range being adequately spaced from the axis of the blank for its formation into flat tubing in

which the fins are within full reach of the interior of the tubing. Within this wide range of fin height, and with available round inner-fin tube blanks of many different fin patterns and sizes, it is possible to obtain widely different flat inner-fin tubing which not only has good heat-exchange properties, but also meets other requirements, such as a specified volumetric flow rate of fluid through the tubing, or to keep pressure drop of passing fluid in the tubing within prescribed limits, for example. Thus, the number of fins, their height within the above wide range, and the peripheral extent of the wall of flat tubing may vary widely to meet many different, including heat-exchange, requirements. Insofar as the height of the fins is concerned, the same is for many, but not all, applications greater than the thickness of the peripheral wall of the tubing.

Reference is now had to Fig. 6 and 7 which show flat inner-fin tubing 10a that basically differs from the described tubing 10 in that the fins 14a on either flat wall section 18a extend with their tips 16a beyond the level of the tips of the fins on the opposite flat wall section but remain spaced from the latter. The flat tubing 10a may otherwise be like the tubing 10 and, hence, formed from the same round inner-fin tube blank 24 (Figs. 4 and 5), with the tubing 10a being formed by the same method as the tube 10, except that the round blank is partially flattened to an extent at which the fins on the opposite flat wall sections interproject. In thus partially flattening the round blank, the fins 14a on the opposite flat wall sections 18a are at, and over the extent of, their crossings 40 interpressed and thereby interlocked due to mutual denting of the fins thereat as at 42 (Fig. 8). Thus, due to the mutual denting of the fins at their crossings in consequence of partially flattening the round blank to the extent of part-way interprojecting the fins on the opposite flat wall sections, the fin pattern as such remains intact and is not distorted (Fig. 7). Owing to the part-way interprojection of the fins in this tubing, the fluid part therethrough is quite tortuous in any event, and may even vary considerably with different degrees of interprojection of the fins. Different interprojection of the fins is thus another tool toward achieving good heat-exchange and meeting other widely varying requirements, such as volumetric flow rate of a fluid passing through the tubing, or to keep pressure drop of the passing fluid within prescribed limits.

Reference is now had to Figs. 9 and 10 which show flat heat-exchange tubing 10b that is formed from a round inner-fin tube blank (not shown) in which the fins extend parallel to the axis of the blank. Thus, in

partially flattening the round blank in accordance with the present method, all the fins 14b in the flat tubing extend parallel to the longitudinal axis  $x$ b. In this exemplary flat tubing, the fins 14b on the opposite flat wall sections 18b interproject to some extent, though it is entirely obvious that by different partial flattening of the blank the fins on the flat opposite wall sections 18b may interproject to a different extent, or the tips of the fins on either flat wall section 18b may with their tips extend to the level of the tips of the fins on the other flat wall section 18b.

In the case of flat tubing of which the fins extend parallel to the longitudinal axis of the tubing, as in Figs. 9 and 10, it is also feasible partially to flatten the round inner-fin tube blank to the extent where the fins on either flat wall section extend with their tips to the opposite wall section, with such heat-exchange tubing 10c being shown in Fig. 11. In this tubing 10c, successive fins 14c divide the interior of the tubing into flow channels 22c which, in contrast to those in the described tubing 10, 10a and 10b, are closed to each other.

In the described flat heat-exchange tubing 10 to 10c, the two opposite flat wall sections constitute the predominant part of the peripheral wall of the tubing. While this is preferred for exacting heat-exchange and also other requirements of many applications, such as cooling the transmission oil of automotive vehicles, just to mention one such application, the advantages of having the fins within full reach of the interior of flat tubing are secured even where the two flat opposite wall sections do not constitute a predominant part, or even constitute less than one-half, of the peripheral wall of the tubing. Thus, Fig. 14 shows flat heat-exchange tubing 10d of which the flat opposite wall sections 18d constitute less than one-half of the peripheral wall 12d of the tubing, with the round inner-fin tube blank (not shown) from which the tubing is fashioned being, in accordance with the present method, partially flattened to an exemplary extent at which the fins 14d on either flat wall section 18d extend with their tips to the level of the tips of the fins on the other flat wall section 18d. Further, the indicated fin height for the also indicated peripheral extent and thickness of the wall of the tubing obviously falls within the aforementioned fin-height range within which the fins in flat tubing are brought within full reach of the interior of the tubing.

Reference is now had to Figs. 15 and 16 which show a heat-exchange unit 50 using a length or piece 52 of flat inner-fin tubing, for example a piece of the flat tube 10a of Figs. 6 and 7. The opposite ends 54 and 56 of the

tube pieces 52 are in communication with the interior of castings 58 and 60, with the tube ends 54 and 56 being fitted in, and conveniently brazed to, slots 62 in the respective casings 58 and 60. The casings 58 and 60 have tapped holes 64 and 66 for connection with conduits through which to lead a fluid, liquid or gas, to and from the unit 50 for temperature modification, such as cooling, for instance.

While in the described heat-exchange unit 50 the end casings 58 and 60 and their slots 62 are rectangular in section (Fig. 16), Fig. 17 shows a heat-exchange unit 70 of which the end casings 72 and 74 are circular in section. To this end, the length of piece 76 of inner-fin tubing is, in its formation from a round inner-fin tube blank, partially flattened only over its longitudinal extent / so that opposite end lengths 78 and 80 of the tubing remain cylindrical, and these cylindrical end lengths 78 and 80 are connected with the casings 72 and 74.

In many heat-exchange applications, the fluid passing through the flat inner-fin tubing is under operating pressure which may be sufficiently high to "open" the tubing by forcing the opposite flat sections of the peripheral wall more or less apart, such as the flat wall sections 18 to 18c of the described tubing 10 to 10c, for example, and thereby greatly reducing the heat-exchange capacity of the tubing, if not rendering the tubing unfit for further use in a particular heat-exchange application. Opening of the tubing in this fashion and from this cause is in many cases prevented by additionally curving or twisting the tubing longitudinally, transversely, or both longitudinally and transversely, and thereby reinforcing the tubing against such opening. Thus, a length 90 of the flat inner-fin tubing may be twisted about its longitudinal axis  $x$  (Fig. 18), whereby the tubing becomes curved, longitudinally as well as transversely, over its lengthwise extent, and is thereby reinforced against opening under internal pressure. The tube length 90 may be twisted by forcing the same through a correspondingly twisting opening in a die 92.

Fig. 19 shows a piece 94 of flat inner-fin tubing which is transversely curved for reinforcement against opening under internal pressure. The initially flat tube piece 94 may to this end be drawn through a die 96 with an opening of the outline of the curved tubing.

Fig. 20 shows a piece 98 of flat inner-fin tubing which is longitudinally curved for reinforcement against opening under internal pressure. This is achieved in this instance by bending the flat tubing around a cylindrical arbor 100. The exemplary tube piece 98 is of quite extensive length with correspondingly large heat-exchange

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capacity, and in order greatly to reduce the lengthwise expanse of the longitudinally curved tubing, the tubing is bent around the arbor 100 in successive and more or less closely adjacent helical turns 102.

While the flat heat-exchange tubing described so far has only inner-fins, such flat tubing may have both, inner and outer fins. Thus, Fig. 21 shows flat heat-exchange tubing 104 which has inner and outer fins 106 and 108. The tubing 104 is, in accordance with the present method, formed from the round inner-and-outer fin tube blank 110 (Fig. 22). The outer fins 108 extend in this instance parallel to the axis of the blank, but they may also extend helically, with the partial flattening of the round tube blank into the flat tubing being in either case entirely feasible on providing companion flattening rolls, for example, with suitable slots for clearing the outer fins.

Reference is now had to Fig. 23 which shows flat heat-exchange tubing 10e that may be like the tubing 10 of Fig. 2, except that there is interposed between the tips 16a of the fins 14e on the opposite flat wall sections 18e a longitudinal strip 112 of any suitable brazing material. One of these strip materials, which is commercially available, is sold under the trade mark SIL-FOS and manufactured by Handy and Harman. The brazing strip 112 is inserted in the course of flattening the initially round inner-fin tube blank into the flat tubing 10c, with the strip 112, which is shown of exaggerated thickness for clarity's sake, being engaged by the tips of the fins. The flat tubing 10e is then heated, as in a furnace 114, for example, to melt the brazing strip 112 and brace the fins together at their crossing tips, with the excess brazing material spreading over nearby portions of the fins. The tubing 10e, being thus brazed together at the crossing tips of the fins, will not open under operational, including particularly high, internal fluid pressures. Brazing of flat tubing at the crossing tips of the fins is indicated where higher internal operational fluid pressures are involved, and especially for applications of such tubing which require that the same remains flat and is not to be curved for reinforcement against opening under internal fluid pressure. Of course, brazing of flat tubing in this manner applies as fully for tubing in which the inner-fins become interpressed in the course of flattening the initially round inner-fin tube blank into the flat tubing, as in Fig. 6, for example.

Reference is hereby drawn to copending Application No. 51818/74 (Serial No. 1390782) (Noranda Metal Industries Inc.), in which there is disclosed and claimed a longitudinal heat exchange tubing com-

prising a peripheral metal wall having two opposite spaced wall sections and two opposite side wall sections joining said opposite spaced wall sections; and spaced metal fins projecting inwardly of the tubing from said wall sections and extending longitudinally of the tubing; and wherein the fins on either of said opposite spaced wall sections are inclined to the longitudinal axis of the tubing so that the ribs on one of said opposite spaced wall sections are inclined to and cross the fins on the other of said opposite spaced wall sections, and the fins on either of said opposite spaced wall sections, and the fins on either of said opposite spaced wall sections extend with their tips beyond the level of the tips of the fins on the other opposite wall section but are spaced from said other opposite wall section.

#### WHAT WE CLAIM IS:—

1. Method of forming longitudinal heat-exchange tubing which comprises providing a round metal tube blank having a longitudinal axis, a peripheral wall about said axis and longitudinal inner fins on said wall, said fins being of equal height and spaced from said axis; and partially flattening the blank from two opposite sides into a substantially oblong cross-section with two opposite, parallel wall sections spaced apart such that the fins on one opposite wall section extend with their tips at least to the level of the tips of the fins on the other opposite wall section.

2. Method of forming longitudinal heat-exchange tubing as in claim 1 in which the blank is partially flattened between rotary companion rolls.

3. Method of forming longitudinal heat-exchange tubing as claimed in claim 1 in which the blank is partially flattened by drawing the same through a die.

4. Method of forming longitudinal heat-exchange tubing as claimed in claim 1, 2 or 3 in which the fins on the peripheral wall of the round tube blank extend helically thereof in parallel relationship whereby in said partial flattening of the blank the fins on said opposite wall sections are inclined to and cross each other.

5. Method of forming longitudinal heat-exchange tubing as claimed in any of claims 1 to 4 in which the blank is partially flattened to space said opposite wall sections a distance apart at which the fins on each opposite wall section extend with their tips beyond the level of the fins on the other opposite wall section but are spaced from the latter.

6. Method of forming longitudinal heat-exchange tubing as claimed in claim 5, in which in the partial flattening of the blank, the fins on the opposite wall sections, respectively, are at their crossings in

terpressed into interlock with each other.

7. Method of forming longitudinal heat-exchange tubing as claimed in any of claims 1 to 6, in which the tubing is subsequently bent longitudinally thereof.

8. Method of forming longitudinal heat-exchange tubing as claimed in any of claims 1 to 7, in which the opposite wall sections are subsequently bent to present an arcuate cross-section.

9. Method of forming longitudinal heat-exchange tubing as claimed in any of claims 1 to 6 in which the tubing is subsequently twisted about its longitudinal axis.

10. Method of forming longitudinal heat-exchange tubing as claimed in any of claims 1 to 6 in which the tubing is subsequently bent into helical form with the opposite wall sections parallel to the axis of the helical form.

11. Method of forming longitudinal heat-exchange tubing as claimed in any of claims 1 to 10 which further comprises, in the course of partially flattening the blank and

before the opposite wall sections reach the desired spacing, inserting between the tips of the fins on said flat wall sections, respectively, a metal brazing strip; and, subsequent to the partial flattening of the blank, heating the tubing to melt said strip and thereby braze the fins on opposite wall sections together at their crossings.

12. Method of forming longitudinal heat-exchange tubing as claimed in any of claims 1 to 11, in which said tube blank is further provided with outer fins on said wall, and said blank is partially flattened from two opposite sides with the outer fins remaining outstanding from said wall.

13. A method of making a heat exchange tubing as claimed in claim 1, substantially as hereinbefore described with reference to the accompanying drawings.

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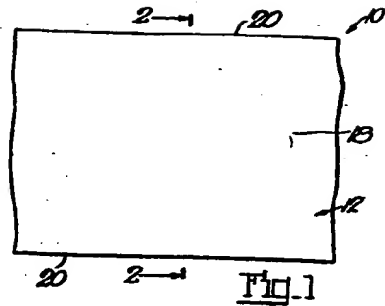


Fig. 1

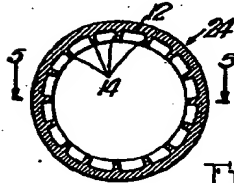


Fig. 4



Fig. 2

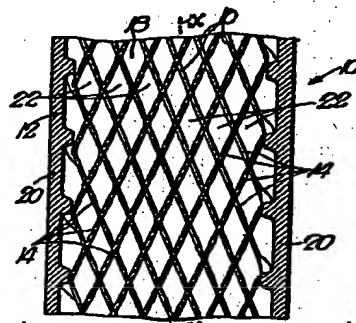


Fig. 3

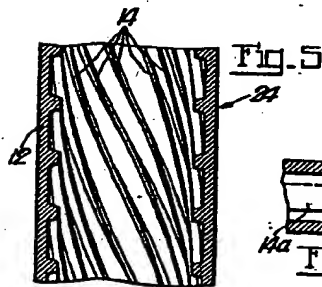


Fig. 5

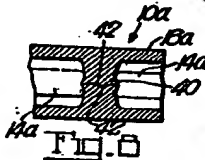


Fig. 6

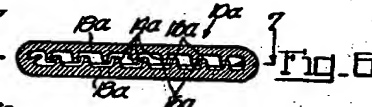


Fig. 6

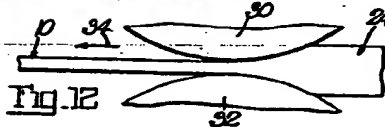


Fig. 12

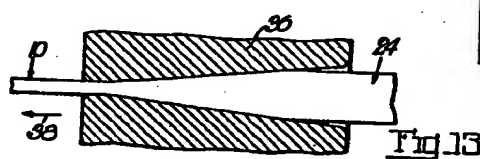


Fig. 13

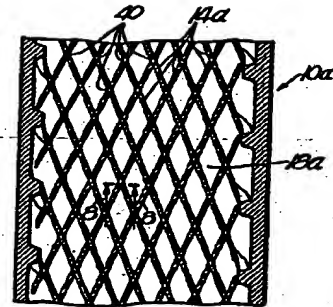


Fig. 7

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Sheet 2

